Technical Memorandum

To:	Hamide Kayaci, Navy Remedial Project Manager		
From:	Jerry Cooper, Gilbane Principal Health Physicist		
Date:	17 Apr 2018		
Subject:	Risk-Based Screening Level Assessment of Fixed Polonium-210 Activity Found on Bollards and Cleats at the Hunters Point Naval Shipyard		
Contract/TO:	N62473-10-D-0808 / CTO 0004	**Gilbane Project No.:**	J204000400

This technical memorandum documents the risk-based screening level assessment that was performed to determine if polonium (Po)-210 activity identified on bollards and cleats at the Hunters Point Naval Shipyard in San Francisco, California, poses an unacceptable risk to human health and warrants further investigation. The screening level assessment concludes that no further action or study of this natural phenomenon is warranted under the Superfund program.

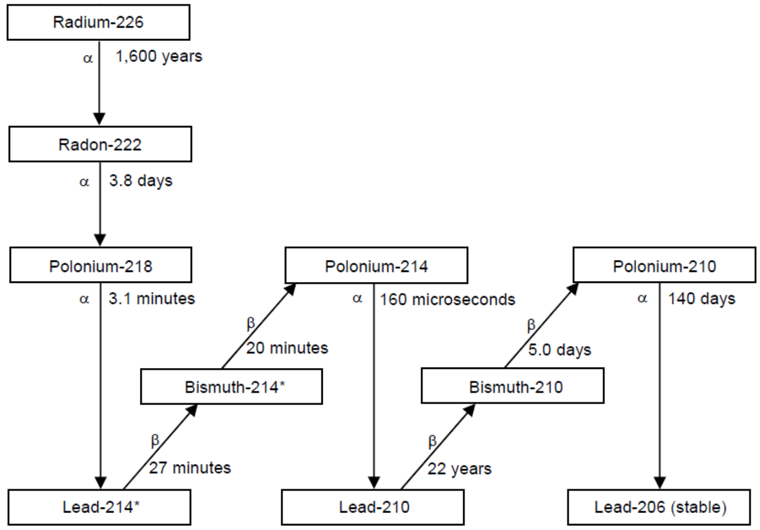
Background

In 2014, Gilbane conducted radiological surveys of ship berth structures, including concrete infrastructure, bollards, and cleats located at the Hunters Point Naval Shipyard. Alpha activity above the release criterion of 100 disintegrations per minute per 100 square centimeters (dpm/100 cm^2) was found on the bollards and cleats at levels up to 400 dpm/100 cm^2. Smear samples of the heavily weathered (i.e., rusted) metal surfaces were collected and no removable alpha activity was found. A sample consisting of metallic shavings, rust particles, and paint scraped from the metal surfaces also was collected and analyzed. Po-210 was found to account for 80 percent of the reported gross alpha activity. No other alpha-emitting radionuclide was identified above its minimum detectable concentration (MDC).

Po-210 is present in nature at very low levels due to its occurrence in the decay series of naturally-occurring uranium-238. The uranium-238 in the Earth's crust decays through a series of atomic transformations that include radium (Ra)-226 and the noble gas radon-222, some of which diffuses into the atmosphere. Radon-222 decays through several more steps to Po-210. Po-210 decays to stable lead (Pb)-206. The figure on the next page shows the Ra-226 decay chain, which constitutes the latter half of the natural uranium-238 decay series from Ra-226 through Pb-206.

While the radionuclides of concern for Hunters Point include Ra-226, the presence of Po-210 cannot be attributed to legacy Navy radiological operations which were discontinued in 1974. Due to its short half-life (140 days) and the long half-life of its progenitor Ra-226 (1,600 years), Po-210 would have reached secular equilibrium many years ago and parent/progenitor radionuclides would be present in comparable concentrations, which they are not. No other alpha-emitting radionuclides - including Ra-226 - were detected in the analysis of the sample collected from the metal surfaces. Some beta-emitting radionuclides were detected, but all at concentrations less than one-half that of Po-210. Consequently, some other source, such as radon decay in the environment, is suspected as the source of the Po-210 plated out on the bollards and cleats. (Gilbane, 2018)

Ra-226 Decay Chain



The plate-out of Po-210 on outdoor metal structures is a recognized phenomenon that has been confirmed at several U.S. Department of Energy sites. The Po-210 deposition is readily observable primarily on galvanized metal surfaces or metal that is rusty, oxidized, or weathered and is possibly due to electrostatic charge. (Abelquist, 2014)

Screening Level Assessment

The U.S. Environmental Protection Agency (EPA) uses risk assessments to characterize the nature and magnitude of health risks to humans (e.g., residents, workers, recreational visitors) from chemical and radiological contaminants that may be present in the environment. The EPA considers the excess cancer risk resulting from the reasonable maximum exposure to an individual in the range of 10^{-4} to 10^{-6} as protective. Exceeding this range suggests that further evaluation of the potential risks is appropriate. Below this range, no further action or study is warranted under the Superfund program.

Screening levels are used to help decision makers identify areas, contaminants, and conditions that may warrant further investigation. For example, preliminary remediation goals for radionuclides on outdoor surfaces (SPRGs) are screening levels for contaminated outdoor hard surfaces such as building slabs, sidewalks, and roads. The SPRG electronic calculator (available at http://epa-sprg.ornl.gov) is a tool developed by the EPA to calculate SPRGs using default input parameters and the EPA's latest toxicity values. SPRG values represent a target risk of 1×10^{-6}, below which no further action or study is warranted under the Superfund program.

Exposure Scenario

Low levels of Po-210 are found naturally in food, water, and air. Po-210 also is found in the human body in small but measurable amounts. It is highly toxic and considered to be one of the most hazardous radioactive materials known. However, for it to be a radiation hazard and exert its toxic effects, it must be taken into the body through breathing (inhalation), eating (ingestion), or by entering the body through a skin abrasion or wound. (CDC, 2010)

In order to create conditions where it can be taken into the body, the metal surface of the bollard or cleat must be abraded to release the fixed Po-210 activity into the environment. To create an inhalation hazard, the material must become airborne. To create an ingestion hazard, it needs to take the form of settled dust on clothing or body parts such as the hands or face, in order to transfer to food or drink and become ingested. The exposure hazard via a skin abrasion or wound is negligible due to its potential for involving no more than a small amount of material.

A reasonable and most likely scenario for the release of the fixed Po-210 activity would be removing rust from the metal surface (e.g., surface grinding using a handheld power grinder) in preparation for painting the bollard or cleat. An activity such as this would not occur incidentally or as a recreational activity. Rather, it would be performed by a worker in a controlled work environment. The worker would be wearing personal protective equipment such as coveralls, a face shield, gloves, and a dust mask. This significantly reduces the availability of the source term, which is the Po-210 activity released into the environment, for either inhalation or ingestion by the worker.

For modeling purposes, the worker is assumed to complete the job and leave the work area without cleaning up the loose material on the ground around the bollard or cleat, and without establishing controls to prevent others from entering the work area. The maximally exposed individual is assumed then to be a recreational visitor in the person of a small child that enters the work area and plays unsupervised in the loose material on the ground around the bollard or cleat. The material transfers from the ground via the child's hand into the child's mouth.

<u>Exposure Pathways</u>

A single exposure pathway is assumed: internal radiation exposure from inadvertent ingestion of radioactive material. This pathway represents the transfer of radioactivity deposited on the ground surface around the bollard or cleat to the mouth via contact with the hands. External exposure to direct radiation from the radioactive material on the ground is negligible due to Po-210 being an alpha emitter and the outer layer of human skin effectively blocking the alpha particles from doing damage from outside the body. Internal radiation exposure from inhalation of airborne radioactive material is assumed to be negligible due to the exposure occurring out of doors in a naturally windy San Francisco Bay location. Airborne radioactive material quickly disperses in the wind. On a calm day, due to its particulate form, it quickly drops from the air and onto the ground as settled dust.

<u>Exposure Events</u>

The exposure is assumed to occur over the course of a single event. Multiple exposure events were considered, but are not deemed credible for two reasons. First, it is unlikely the loose radioactive material on the ground would remain in place in any significant concentration over multiple days due to the wind and rain that are common to the area. Second, the risk to the dose receptor, which is an unattended child near the water's edge, posed by drowning due to multiple exposure events far exceeds and effectively negates the incrementally increased risk posed by the radiation hazard.

Source Term

The source term is assumed to be composed of Po-210 equivalent to an average concentration of 200 dpm/100 cm^2 fixed on the metal surface of the bollard or cleat. This assumption is based on the survey and sampling performed. Pre- and post-surveys performed of the metal surfaces from which the sample was collected showed the average alpha activity removed was 250 dpm/100 cm^2 and laboratory analytical results indicated 80 percent of the removed gross alpha activity was Po-210 (Gilbane, 2018). The source term is assumed to be distributed on the ground in a 5 square meter (m^2) area around the bollard or cleat.

For modeling purposes, the source term also is assumed to include Po-210 progenitors bismuth (Bi)-210 and Pb-210, both of which are beta emitters, and all in secular equilibrium. This is consistent with the sampling results, which found near equal concentrations of both gross alpha and gross beta activity. While Po-210 was found to account for 80 percent of the reported gross alpha activity, Pb-210 was found to account for 40 percent of the reported gross beta activity. A variety of other beta-emitting radionuclides also were identified above their respective MDC, though none of them made up more than 10 percent of the gross beta activity. (Gilbane, 2018)

Modeling Parameters

Modeling parameters, their definitions, and default values used by the SPRG calculator are found in the SPRG User's Guide on the Internet (https://epa-sprg.ornl.gov/sprg_users_guide.html). Since the single exposure pathway is based on ingestion, the key scenario-specific modeling parameters relate to the transfer of the radioactive material from the ground to the mouth. Those parameters, their values, and referenced sources are taken from the SPRG User's Guide and are shown in the following table.

Key Scenario-Specific Modeling Parameters

Parameter	*Value Used*	*Reference*
Surface Area of Fingers – Child (cm^2)	16	EPA, 2011. Table 7.2 (5 percent of the average of adult male and female)
Transfer Fraction Surface to Skin – Hard Surface (unitless)	0.5	EPA, 2003. Page D-3
Frequency of Hand-to-Mouth Child Outdoor (events/hour)	10	EPA, 2011. Table 4.1 (time weighted average of all age groups from birth to 6 years)
Saliva Extraction Factor (unitless)	0.5	EPA, 2003. Page D-5
Exposure Time – Child Hard Surface (hours/day)	4	EPA, 2003. Page D-4

The table on the following page lists additional modeling parameters where scenario-specific values are used. All other modeling parameters remain at default values used by the SPRG calculator.

Additional Scenario-Specific Modeling Parameters

Modeling Parameter	***Value Used***	***Basis***
Exposure scenario	Outdoor worker	Most appropriate SPRG calculator scenario option
Media	dust	Radioactive material assumed to be in nature of settled dust
Radionuclides[a]	Po-210, Bi-210, Pb-210	Gilbane, 2018.
Exposure duration (years)	1	Single exposure event assumed (default = 25 years)
Exposure frequency (days/year)	1	Single exposure event assumed (default = 250 days/year)
Source area (m^2)	5	Assumed area of radioactive material on ground surface

Note:
[a] Po-210 and Bi-210 assumed to be in secular equilibrium with Pb-210.

Results and Discussion

The SPRG for the ingestion of Po-210 is 0.163 becquerels per square centimeter (Bq/cm^2), which converts to 978 dpm/100 cm^2 (conversion factor: 1 Bq/cm^2 = 6,000 dpm/100 cm^2). This value was calculated using the SPRG calculator based on the exposure scenario and modeling parameters discussed above. It equates to a target cancer risk of 1 x 10^{-6}. The SPRG calculator scenario-specific inputs and results are attached. The calculated ingestion SPRG for Po-210 (978 dpm/100 cm^2) is significantly higher than the source term concentration assumed for this exposure scenario (200 dpm/100 cm^2). The equivalent cancer risk would be 2.0 x 10^{-7}.

According to the exposure scenario, the source term is removed from the metal surface by grinding. It becomes airborne and some fraction of it is carried off by the wind. The rest then deposits onto the ground as settled dust over a larger area than the area from which it was removed. For example, source term removed from a 2 m^2 area on the bollard or cleat may settle on the ground as loose material over a 4 m^2 area, which dilutes its concentration by one-half. While no attempt is made to quantify it, the diluted concentration of loose material on the ground available to be ingested would be significantly less than the original 200 dpm/100 cm^2 source term concentration. Accordingly, the equivalent risk likewise would be significantly less than 2.0 x 10^{-7}.

Conclusion

The excess cancer risk for the maximally exposed individual (i.e., the recreational visitor in the person of a small child) is below the risk range of 10^{-4} to 10^{-6} which the EPA considers as protective of human health. Therefore, no further action or study is warranted under the Superfund program.

Attachment

SPRG Calculator Scenario-Specific Inputs and Results (5 pages)

References

Abelquist, Eric W. *Decommissioning Health Physics: A Handbook for MARSSIM Users, Second Edition*. CRC Press, New York. 2014.

CDC (Centers for Disease Control), 2010. *Frequently Asked Questions about Polonium 210*. Available at https://www.cdc.gov/nceh/radiation/fallon/polonium_factsheet.pdf.

EPA, 2003. *World Trade Center Indoor Environmental Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks*. Prepared by the Contaminants of Potential Concern (COPC) Committee of the World Trade Center Indoor Air Task Force Working Group.

EPA, 2011. *Exposure Factors Handbook 2011 Edition (Final)*. National Center for Environmental Assessment, Office of Research and Development. Washington D.C.

Gilbane, 2018. Technical Memorandum entitled: *Technical Approach: Elevated Alpha Surface Activity on Weathered Outdoor Metal Surfaces; Parcel D-1 Phase II Radiological Remediation and Support, Hunters Point Naval Shipyard*. January 23.

Site-specific
Outdoor Worker Equation Inputs for Dust

Variable	Value
TR (target cancer risk) unitless	0.000001
k (dissipation rate constant) yr^{-1}	0.0
EF_{ow} (exposure frequency) day/yr	1
F_{AM} (area and material factor) unitless	1
ET_{ow} (worker exposure time) hr/day	4
t_{ow} (time - worker) yr	1
$F_{OFF-SET}$ (off-set factor) unitless	1
SLF (Silt Loading Factor) cm^2/kg	6.67E+08
GSF_s (outdoor surfaces gamma shielding factor) unitless	1
IFD_{ow} (dust ingestion factor - outdoor worker) cm^2	160
IRA_{ow} (dust inhalation rate - outdoor worker) m^3/hr	2.5
ED_{ow} (exposure duration - outdoor worker) yr	1
Slab size for ACF (area correction factor) m^2	5
$FTSS_h$ (fraction transferred surface to skin - hard surface) unitless	0.5
SE (saliva extraction factor) unitless	0.5
SA_{ow} (surface area of fingers - outdoor worker) cm^2	16
FQ_{ow} (frequency of hand to mouth - outdoor worker) events/hr	10
City (Climatic Zone) PEF Selection	29
A_s (acres)	0.5
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
F(x) (function dependent on U_m/U_t derived using Cowherd et al. (1985)) unitle	0.194
PEF_w (Wind Particulate Emission Factor) m^3/kg	1359292542.2557
A (Dispersion Constant) - wind	16.2302
B (Dispersion Constant) - wind	18.7762
C (Dispersion Constant) - wind	216.108
PEF_{m-pp} (Mechanical Particulate Emission Factor - paved public) m^3/kg	NaN
Q/C_m (inverse of the ratio of the geometric mean air concentration to the emission flux	23.017850304789
A (Dispersion Constant) - mechanical	12.9351
B (Dispersion Constant) - mechanical	5.7383
C (Dispersion Constant) - mecahnical	71.7711
t_c (exposure interval) hours	8760

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Site-specific
Outdoor Worker Equation Inputs for Dust

Variable	Value
T (exposure interval) s	31536000
W_R / Width of road segment (ft)	20
L_R / Length of road segment (ft); Calculated from As above.	147.58048651498
F_D (Dispersion correction factor) unitless	0.1858110274519
A_R / Area (m^2)	274.21339877403
k-pp / Particle size multiplier for public-paved road (g/VKT)	0.62
sL / Road surface silt loading (g/m^2)	0.015
W / (mean vehicle weight) tons	NaN
p / number of days in a year with at least 0.001 inches of precipitation	150
∑ VKT / Sum of fleet vehicle kilometers traveled during ED (km/yr)	NaN
km per road class	0.0449825322897

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Site-specific

Outdoor Worker Surface Preliminary Remediation Goals for Dust - Progeny Included (with decay)

Radionuclide	Adult Soil Ingestion Slope Factor (risk/Bq)	Inhalation Slope Factor (risk/Bq)	Ground Plane External Exposure Slope Factor (risk/yr per Bq/cm^2)	Lambda (1/yr)	Halflife (yr)	Decay	Dissipation	Area Correction Factor	PEF_w	PEF_m
Bi-210	1.01E-10	1.23E-08	1.30E-07	3.12E-02	2.22E+01	3.07E-02	1.00E+00	1.27E-01	1.36E+09	-
Hg-206	0.00E+00	0.00E+00	3.03E-06	3.12E-02	2.22E+01	3.07E-02	1.00E+00	1.26E-01	1.36E+09	-
Pb-210	1.62E-08	4.30E-07	4.65E-08	3.12E-02	2.22E+01	3.07E-02	1.00E+00	3.95E-01	1.36E+09	-
Po-210	3.89E-08	3.92E-07	2.35E-10	3.12E-02	2.22E+01	3.07E-02	1.00E+00	1.02E-01	1.36E+09	-
Tl-206	0.00E+00	0.00E+00	2.32E-07	3.12E-02	2.22E+01	3.07E-02	1.00E+00	2.16E-01	1.36E+09	-

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Site-specific

Outdoor Worker Surface Preliminary Remediation Goals for Dust - Progeny Included (with decay)

Radionuclide	Ingestion SPRG TR=0.000001 (Bq/cm²)	Inhalation Mechanical SPRG TR=0.000001 (Bq/cm²)	Inhalation Wind SPRG TR=0.000001 (Bq/cm²)	External Exposure SPRG TR=0.000001 (Bq/cm²)	SPRG Wind TR=0.000001 (Bq/cm²)
Bi-210	6.28E+01	-	1.68E+01	1.34E+05	**1.33E+01**
Hg-206	-	-	-	5.84E+03	**5.84E+03**
Pb-210	3.92E-01	-	4.82E-01	1.21E+05	**2.16E-01**
Po-210	1.63E-01	-	5.28E-01	9.30E+07	**1.25E-01**
Tl-206	-	-	-	4.44E+04	**4.44E+04**

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Site-specific

Outdoor Worker Surface Preliminary Remediation Goals for Dust - Progeny Included (with decay)

Radionuclide	SPRG Mechanical TR=0.000001 (Bq/cm²)	SPRG Wind TR=0.000001 (mg/cm²)	SPRG Mechanical TR=0.000001 (mg/cm²)
Bi-210	**6.28E+01**	4.68E-09	2.21E-08
Hg-206	**5.84E+03**	2.02E-06	2.02E-06
Pb-210	**3.92E-01**	7.63E-11	1.38E-10
Po-210	**1.63E-01**	4.40E-11	5.75E-11
Tl-206	**4.44E+04**	1.54E-05	1.54E-05

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